APPLICATION FOR UNITED STATES LETTERS PATENT

TITLE:

SEMI-CYLINDRICAL TYPE PARACHUTE

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SEMI-CYLINDRICAL TYPE PARACHUTE

1. Field of the Invention:

[001] The present invention relates to the field of parachutes and, more particularly, to a novel type of parachute that will equal, or surpass, the performance characteristics of a conventional semi-spherical ballistic type parachute and, in some ways, controllably mimic the performance characteristics of a higher performance, parafoil type, gliding wing, parachute.

2. Description of the Prior Art

[002] In general terms, for personnel use, and for the aerial delivery of cargo, there are two types of parachutes in use today. One type is the semi-spherical ballistic, drag producing, parachute, commonly known in the trade as a round parachute, although it is typically constructed as a polygon. The other type is a ram-air inflatable wing, which is a lift producing, gliding parachute, commonly known in the trade as a parafoil or a square parachute, although it is generally rectangular or elliptical in plan form.

a. Ballistic Parachutes

[003] The semi-spherical ballistic, type parachute has been in use for many, many, decades and continues to be the most widely used parachute type, by a huge margin. Performance of this type of parachute is almost entirely dependent on drag because it has extremely little gliding or lift generating capability. In many instances, having no true gliding capability, drifting only where the wind carries it, is not only acceptable, it is quite desirable. For instance; during mass parachute deployments of military troops or equipment, the non-gliding feature of the semi-spherical ballistic, type parachutes allows these uncontrolled parachutes to generally maintain

relative separation. This feature greatly reduces the opportunities for parachute collisions and subsequent entanglements.

[004] Semi-spherical ballistic parachute canopies are occasionally provided with directional venting, which allows them to be steered to a desired heading, but their gliding performance is extremely low. Even though this steering technique has been known for many years, parachutes having this configuration are used very little and, when used, are used almost exclusively as personnel parachutes. By lacking the capability for traversing through an air mass and the high cost for guidance and control, this type of parachute has not generally been considered to be sufficiently effective for guided cargo aerial delivery systems.

[005] While it is much less costly to fabricate a semi-spherical ballistic type parachute than a parafoil type parachute, of the same general size, construction of the semi-spherical ballistic type of parachute is, nevertheless, not especially efficient use of the fabric from which it is constructed. A typical semi-spherical ballistic type parachute canopy is generally constructed from multiple triangular gore panels that radiate from a central point. Generally, the gore panels are truncated to provide the parachute canopy with a centrally located vent and, occasionally, the triangular gore shape is slightly modified to provide a more aerodynamically appropriate shape for a specific application. Extending outward from the canopy skirt, generally from the radial seams that join the gores, are suspension members with a length that generally approximate the constructed diameter of the canopy.

[006] The horizontal profile of the canopy of a ballistic parachute, when inflated into a spherical cap, will be less than the surface area of the canopy resulting in a projected diameter that is reduced by approximately one third of its constructed diameter. An undesirable

consequence of a semi-spherical ballistic canopy that has been effectively reduced by approximately 33.3% of its constructed diameter is that it projects a drag area that has been reduced by approximately 44.4% of its constructed area.

b. Parafoil-type Parachutes

[007] The parafoil type parachute is a ram-air inflatable wing and requires a relatively fast forward glide velocity to produce lift; just as the forward velocity of an airplane wing produces lift. The parafoil type parachute is also quite maneuverable. The gliding and lift producing characteristics of the parafoil type parachute, coupled with omnidirectional steering, allows it to glide long distances and be accurately maneuvered to a precise landing point. The attributes of the parafoil type parachute make it the overwhelming choice for modern day skydivers and military operations when precision landing of troops or cargo is desirable.

[008] The very features that make the parafoil type parachute extremely desirable for some select applications make it much less desirable for other applications, however. Properties that allow the parafoil type parachute to glide long distances, and be highly maneuverable, require that it have a costly guidance and control system for delivering cargo to precise target locations or that it be operated by only highly skilled parachutists when used as a personnel parachute.

[009] The semi-spherical ballistic, type parachute, even coupled with a guidance and control system, is typically inadequate for accurate target attainment but the parafoil type parachute may have excessive capabilities and, in some instances, introduce more problems than it solves. The properties that permit this type of parachute to be guided to a very specific target will also allow it to reach a point very distant from the desired target if not steered correctly. Additionally, even though parachutists using the parafoil type parachutes are typically very skilled, some number of

deaths occur each year as the result of high speed landings or midair collisions with fellow parachutists and/or the ensuing entanglements that cause crash landings after the entangled parafoils lose their forward velocity and, consequently, their lift. Moreover, the parafoil type parachutes are very labor intensive to fabricate and are, therefore, quite costly when compared to a semi-spherical ballistic type parachute of the same general size.

[010] Many large scale users of parachute systems, such as military organizations, find themselves in a dilemma: Generally, a choice must be made between a simple low cost, semi-spherical ballistic type parachute system, having very little target acquisition capability, or a high cost, high performance, parafoil type parachute system, requiring a sophisticated guidance and control system or highly skilled parachutists to operate reliably. In actual practice, many large scale users of parachutes must maintain both types of parachute systems in their inventory.

[011] When properly inflated, the semi-spherical ballistic type parachute canopy will be reduced around its entire circumference, resulting in a projected diameter that is reduced by approximately one third of its constructed diameter. An undesirable consequence of a semi-spherical ballistic canopy that has been effectively reduced by approximately 33.3% of its constructed diameter is that it projects a drag area that has been reduced by approximately 44.4% of its constructed area. The outermost circle of Fig 4 illustrates the constructed area of a semi-spherical ballistic type parachute canopy and the shaded portion of the figure depicts the relative inflated size. Additionally, the semi-spherical ballistic parachute has very little capability for altering its ballistic path to enable it to reach a specific target.

[012] Parafoil type parachute canopies are multiple cell, airfoil shaped, ram-air inflatable, wings made of many complex panel shapes requiring demanding fabrication processes. To

establish the rigging angle necessary to achieve a desired glide angle, and maintain the desired airfoil shape, great variation in the length of the suspension lines is necessary, depending on their designated locations. When properly inflated, a parafoil type parachute has a generally rectangular, or elliptical, plan form, and, quite frequently, has a span that is approximately 250% of its chord. While parafoils have very impressive flight characteristics, if not properly controlled during flight, they can miss their intended targets by huge amounts and, if not properly controlled at landing, can severely damage delivered payloads and injure or kill parachutists.

SUMMARY OF THE INVENTION

[013] In accordance with the present invention, there is provided a very simple technique that can be used to design a parachute canopy that will provide approximately 50% more projected drag area than a semi-spherical ballistic type parachute canopy when constructed from a given amount of fabric. Furthermore, this basic canopy design will produce a parachute that will have, selectively, moderate glide performance along with favorable maneuvering capabilities. This novel parachute, while descending, can transition, controllably, from ballistic, to gliding, and from gliding to ballistic, as circumstances dictate. Beyond that, this parachute design allows for a simple control feature that enables its vertical velocity to be adjusted so that it exceeds the nominal descent rate or decreased to less than the nominal descent rate. The inflated canopy shape of this parachute is roughly that of a half cylinder and it is referred to as a semi-cylindrical type parachute.

[014] The canopy for the semi-cylindrical type parachute is fabricated of gores, somewhat like the gores of a semi-spherical ballistic parachute canopy, but they are inverted, relative to a

semi-spherical ballistic parachute, and appear as narrow canopy segments, joined side by side, with longitudinal seams This geometry results in a parachute canopy that is constructed as a generally rectangular plan form, instead of a circular plan form. The simple design feature of inverting the gores has a profound impact on the resulting canopy shape and, consequently, the parachute performance capabilities.

[015] A semi-cylindrical type parachute canopy, constructed from an identical amount of fabric as a semi-spherical ballistic canopy, when properly inflated, will have a size reduction in the chordwise direction only and will, therefore, have a projected drag area that is approximately 66.7% of the constructed area. The outermost lines of Fig 5 illustrate the constructed area of a semi-cylindrical type parachute canopy and the shaded area of the figure illustrates the relative inflated size. As the result of this configuration, the projected drag area of the semi-cylindrical type parachute canopy, for an equal amount of fabric, has approximately 150% of the projected drag area of a semi-spherical ballistic type parachute canopy. For the user, this means that, for a specific amount of suspended weight, the canopy size can be reduced by approximately 33.3%. Or, for a specific amount of fabric, the amount of suspended weight can be increased by approximately 50%.

[016] When compared to a semi-spherical ballistic parachute, a parafoil type parachute, of the same general size, is very costly. In many instances, the increased cost for the parafoil type parachute is considered to be worthwhile because it provides a parachute that can efficiently traverse an air column in which it is descending and has good target reaching capabilities. However, if the parafoil type parachute is not properly controlled, its high performance features can cause it to miss the intended target by huge factors. Additionally, because of the high velocity gliding feature of the parafoil type parachute, landings are a particular problem. To

reduce the velocity of autonomously guided parafoil type cargo delivery systems, it is very desirable to have an accurate altitude sensing device, such as a radar altimeter, coupled to the controlling device to cause a precisely timed flared landing maneuver. Obviously, such sophisticated equipment is very costly. For parachutists, on the other hand, it is necessary to clearly see the landing spot and have the proper skills to correctly perform the precisely timed flared landing maneuver, at the precise altitude, that will contribute to landing safely.

[017] The semi-cylindrical type parachute has improved ballistic performance over the semi-spherical ballistic type parachute and, selectively, many of the steering and maneuvering characteristics of the parafoil type parachute, although to a lesser degree. Moreover, by landing ballistically, the semi-cylindrical type parachute is not dependent on a precisely timed flared landing maneuver to decrease landing velocity.

[018] In some instances, it is quite desirable to maneuver a parachute to a point above a target and then maintain that general position. The unique performance capabilities of the semi-cylindrical type parachute allows this to be done quite conveniently.

[019] The semi-cylindrical type parachute can be deployed as a ballistic parachute then, if desired, it can selectively transition to become a gliding, steerable, parachute, having performance characteristics somewhat like the parafoil type parachute, to reach a specific target area. Over the target, or on the glide path to the target, the parachute can, selectively, transition into a ballistic parachute, again. Depending on specific needs, the descent rate of the semi-cylindrical type parachute can be altered to cause a rate that is above nominal or below nominal. This combination of features is not attainable with either the semi-spherical ballistic type parachute or the parafoil type parachute.

[020] Even though the semi-spherical ballistic type parachute is considered to be generally ballistic, by retracting the suspension members on one side and/or extending the suspension members on the opposite side, the canopy skirt will be caused to tilt, relative to horizontal, and relatively high pressure air from the canopy interior will vent from beneath the elevated side of the canopy skirt and push the parachute in the opposite direction. Because the inflated parachute canopy is roughly hemispherical, not at all wing-like, extremely little lift is generated and the traversing movement, known a slipping, is very inefficient.

[021] It is not uncommon for slipping maneuvers to be accomplished with slip-riser assemblies. Conventionally, one slip-riser assembly is used for the left side of the parachute assembly and another slip-riser assembly is used for the right side. Each slip-riser assembly typically consists of a front riser leg joined to a rear riser leg and is configured to cause a rear riser leg extension as the result of a front riser leg retraction, and vise versa. This process, while enabling a semi-spherical ballistic parachute canopy to move transversally, will not cause it to quickly change heading by spinning or spiraling as part of the process, however. The insignificant rotational capability provides a parachutist, or the operator of a semi-spherical ballistic parachute cargo delivery system, very little heading control, relative to wind direction. A choice of heading may be especially desirable when landing. Statistically, and randomly, 25% of all landings, when using conventional semi-spherical ballistic parachutes, will be landings with forward drift, landings with left or right drift will be split evenly, with 25% in each direction, and 25% will be landings while drifting to the rear. Regardless of the skill of the parachutist, a rearward landing is more likely to result in injury than is a landing with drift in any other direction. Use of the semi-cylindrical type parachute will allow a great majority of landings to have the most desirable heading for the particular circumstance.

[022] It is therefore an object of the invention to provide a novel parachute design that will efficiently fulfill all the performance requirements of the low cost, low performance, semi-spherical ballistic type parachute and many of the requirements of the high cost, high performance, parafoil type parachute with a simple to construct, low cost, parachute.

[023] It is another object of the invention to provide a parachute having a canopy with a generally rectangular plan form.

[024] It is another object of the invention to provide a parachute that is selectively ballistic or gliding.

[025] It is another object of the invention to provide a parachute that is selectively steerable.

[026] It is another object of the invention to provide a parachute with a selectively variable descent rate.

[027] It is another object of the invention to provide a parachute with efficient materials utilization.

BRIEF DESCRIPTION OF THE DRAWINGS

[028] A complete understanding of the present invention may be obtained by reference to the accompanying drawings, when considered in conjunction with the subsequent, detailed description, in which:

[029] Figure 1 is a perspective view of a properly inflated semi-cylindrical type parachute having a canopy assembly, trapezoidal gores, canopy segments, longitudinal seams, end panels, suspension lines, and slip-riser assemblies;

[030] Figure 2 is a plan view of a trapezoidal gore;

[031] Figure 3 is a plan view of a canopy segment comprised of two trapezoidal gores;

[032] Figure 4 is a plan view of a conventional semi-spherical ballistic parachute canopy, having a constructed area and an inflated area;

[033] Figure 5 is a plan view of a semi-cylindrical type parachute canopy, having a constructed area and an inflated area;

[034] Figure 6 is a plan view of a parachute canopy having conventional semi-spherical ballistic geometry; and

[035] Figure 7 is an elevational view of a semicircular end panel.

[036] For purposes of clarity and brevity, like elements and components will bear the same designations and numbering throughout the FIGURES.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[037] Figure 6 illustrates a conventional, semispherical ballistic parachute **24** in plan view. The semispherical ballistic parachute **24** is constructed of a plurality of gores arranged radially around a central circular panel or vent. The gores are generally trapezoidal in shape, with a smaller base disposed at the center of the semispherical ballistic parachute **24** and a larger base at the perimeter or "skirt" of the parachute. Each of the long sides **28** of each gore **26** are conjoined with the opposing long side of the adjacent gores, forming a radial seam **30** between the gores **26**. The long sides **28** of each gore **26** may be straight, or arcuate, to provide a shape more of a spherical segment when the parachute is inflated.

[038] In Figure 4, the horizontal or plan areas of the uninflated and inflated semispherical ballistic parachute **24** are compared. The uninflated area represents the area of the deflated parachute on a flat horizontal surface, and is proportional to the amount of fabric required to construct the parachute. The inflated area **34**, shown within the cross-hatched area of Figure 4, represents the area of the inflated semispherical ballistic parachute **24**, when it has taken the shape of a spherical segment, projected on a horizontal plane. This horizontal inflated area **34** is proportional to the amount of drag provided by the ballistic semispherical parachute. The ratio of the projected uninflated area **32** to the inflated area **34** on the horizontal plane represents the drag efficiency provided by the parachute design.

[039] To achieve the objectives of providing a parachute design with an improved drag efficiency over a ballistic parachute, in addition to providing one with some gliding or maneuvering improvements over a ballistic parachute, a semi-cylindrical parachute **10** is provided, as shown in Figure 1. The semi-cylindrical parachute **10** is comprised of a canopy assembly **12**, which in turn is comprised of a number of canopy segments **16**. The preferred number of canopy segments **16** comprising the canopy assembly **12** is seven. At either end of the canopy assembly **12** is an end panel **18**. Each end panel **18** has a curved, preferably semi-circular upper edge, which forms a seam with the outer longitudinal edge of the adjacent canopy panel. The completed canopy has, when inflated, a generally semi-cylindrical shape around the horizontal axis.

[040] A number of suspension lines **20** are connected to the canopy assembly **12**, from which the supported load is suspended. The upper end of each suspension line **20** is attached to the skirt of the canopy assembly **12** at a seam between adjacent canopy segment **16** and between end

panels **18** and adjacent canopy segment **16**. The lower ends of the suspension lines **20** are assembled together with a pair of slip-riser assemblies, as commonly used in the art.

[041] In Figure 2, one of the two gores **14** which comprises each canopy segment **16** is illustrated. Each gore **14** is generally in a trapezoidal shape fabricated from a single layer of fabric, with two parallel bases; a longer base **38** and a shorter other base. Two longitudinal sides **42** of the gore taper inward from the larger base to the shorter base **40**. The longitudinal sides **42** may be straight or arcuate, depending on the desired shape of the inflated canopy.

[042] In Figure 2, an assembled canopy segment **16** is illustrated. Each canopy segment **16** is comprised of two gores **14**, in reverse orientation to each other with the two longer bases **38** abutting to form a centerline span **44**. The two shorter bases **40** of the gores **14** are parallel and at opposite ends of the canopy panel.

[043] The end panel **18** is illustrated in Figure 8. It is comprised of a single layer of fabric and is cut into a shape with a substantially straight lower edge **46** and an arcuate or curved upper edge **36**. The ends of the upper edge **36** are disposed at either end of the lower edge **46**. In the preferred embodiment, the upper edge **36** is semicircular in shape, with a center of radius located at the center of the lower edge **46**.

[044] The parts of the canopy are illustrated in Figure 8, prior to assembly. A plurality of canopy segments **16**, preferably seven, are aligned laterally with centerline spans **44** and either ends of the canopy segments collinearly aligned. The longitudinal sides **42** of adjacent canopy segment **16** are conjoined in a seam. The upper edge **36** of each end panel **18** and the outer longitudinal side **42** of the outer canopy segment **16** are conjoined in a seam; forming a single layer canopy.

[045] Figure 1 is a perspective view of a semi-cylindrical type parachute assembly **10**. This semi-cylindrical type parachute assembly **10** consists of a generally semi-cylindrical canopy assembly **12**, of an approximately 2.0:1 span to chord aspect ratio when properly inflated, comprised of a plurality of canopy segments. Each canopy segment is comprised of a single layer of fabric having two longitudinal edges and two parallel end edges. This semi-spherical type parachute assembly has trapezoidal gores **14**, combined as canopy segments **16**, having anhedral arc incorporated as the result of the trapezoidal gore **14** orientation, along with semicircular end panels **18**, in addition to suspension lines **20**, and slip-riser assemblies **22**, that when combined, in series, have a length that is approximately equal to 100% of the canopy assembly **12** span.

[046] To fabricate the semi-cylindrical parachute **10**, begin with a selected inflated area, of an approximately 2.0:1 span to chord aspect ratio; multiply the span dimension by 0.392 to obtain a centerline chord dimension for the design of a trapezoidal gore **14**. Divide the span dimension by the desired number of canopy segments **16**, which is seven in the preferred embodiment, to obtain a design dimension for the span, or longer base **38** of each trapezoidal gore **14**. Multiply the span dimension of the trapezoidal gore **14** by 0.8 to obtain a design dimension for the skirt, or a shorter base **40** of each trapezoidal gore **14**. Multiply the resulting trapezoidal gore **14** hypotenuse dimension by 2 and divide by pi to obtain a design radius for a semicircular end panel **18**. Multiply the span dimension by 1.0 to obtain the design length dimension for each suspension line **20** and slip-riser assembly **22** serial combination.

[047] After providing for typical seam and hem allowances, cut fourteen trapezoidal gores **14**, as illustrated by Fig 2, from an appropriate fabric and join them, as pairs, along their longer bases **38** to form seven canopy segments **16**, as illustrated by Fig 3. Join the canopy segments **16**, in

series, along their longitudinal sides **42**, to form a roughly rectangular canopy assembly **12** having a constructed chord dimension that is approximately 80% of the span dimension. Provide for typical seam and hem allowances and cut two semicircular end panels **18** from an appropriate fabric. Install an end panel **18** by its upper edge **36** in each outboard longitudinal side **42** of the canopy assembly **12**, as depicted by Fig 1. Mark and cut sixteen suspension lines **20**, that when joined, serially, to the riser assemblies **22**, will have a finished dimension that is approximately 100% of the canopy assembly **12** span dimension. Install one suspension line **20** at the intersection of the canopy assembly **12** skirt and each longitudinal seam **48**. Cut, and attach, six similar suspension lines **20**, equally spaced, to the skirt of each end panel **18**. Connect the free end of each suspension line **20** extending from the left front quarter of the canopy assembly **12** periphery to the left front slip-riser assembly **22** leg. Connect the free end of each suspension line **20** extending from the right front quarter of the canopy assembly **12** periphery to the right front slip-riser assembly **22** leg. Connect the free end of each suspension line **20** extending from the left rear quarter of the canopy assembly **12** periphery to the left rear slip-riser assembly **22** leg. Connect the free end of each suspension line **20** extending from the right rear quarter of the canopy assembly **12** periphery to the right rear slip-riser assembly **22** leg.

[048] It is quite feasible for the semi-cylindrical type parachute **10** to utilize conventional slip-riser assemblies **22** if controlled maneuvering is desired. When using the slip-riser maneuvering technique, the slip-riser assemblies **22** for both sides of the parachute **10** can be manipulated, in unison, to cause a forward glide. By reversing the riser positions, a rearward glide will be produced. Because the semi-cylindrical type parachute **10** canopy plan form is much more wing-like than the canopy of the semispherical ballistic parachute **24**, the gliding performance is considerably more pronounced, and efficient, than that of a parachute having a semispherical

ballistic canopy. If the slip-riser assembly **22** on only one side of the parachute **10** is manipulated, the semi-cylindrical type parachute will make a heading change and the canopy can then be caused to glide in a new direction. Or, if desired, it can simply maintain the new heading, without glide. If an increased rate of descent is desired, the slip-riser assembly **22** on one side can be manipulated to cause a turn and, if the riser position remains unchanged, a spiraling turn will result.

[049] Spiraling turns are aerodynamically inefficient and the rate of descent will increase as a result. If, on the other hand, the riser assembly on one side is manipulated to cause a turn in one direction and the opposite riser assembly is manipulated in a similar fashion, the semi-cylindrical type parachute canopy will twist to become somewhat propeller-like, and spin about its vertical axis, producing lift, just as the spinning blades of a helicopter produce lift if the helicopter engine has lost power. Logically, when the parachute canopy begins producing lift it will have a decrease in its relative rate of descent.

[050] The very unique maneuvering capabilities of the semi-cylindrical type parachute **10**, coupled with excellent economy of construction, is not known to exist with any other parachute type.

[051] As for parachutes of many other types, the designer of a semi-cylindrical type parachute **10** canopy can select from fabric offering the most desirable degree of permeability for a specific application, or the canopy can be made from strips of fabric, or ribbons, or be produced with specifically sized and located orifices, to produce a canopy with a specific geometric porosity and/or directional venting.

[052] It has been learned that the performance of the semi-cylindrical type parachute can be enhanced by having an end panel **18** installed in each end of the semi-cylindrical canopy assembly **12** to inhibit transverse airflow from the canopy interior. A semicircular end panel **18**, completely filling the opening at each end of the semi-cylindrical type parachute canopy, as depicted by Fig 1, is most effective but a partial panel, such as one shaped as a crescent, is somewhat effective and has less bulk than a semicircular end panel. However, a complete semi-circular end panel will cause the inflated canopy shape to become somewhat elliptical, and will slightly increase the canopy span.

[053] As is true for any type of wing-like gliding device, the gliding performance of the semi-cylindrical type parachute can be enhanced by increasing the span ratio, relative to the chord. The size and aspect ratio of the semi-cylindrical type parachute canopy is primarily dependent on the number of canopy segments utilized and/or the size of the canopy segments.

[054] Depending on loading conditions, it may be desirable to install suspension lines on the end panels of the semi-cylindrical type parachute canopy. Specific loading factors will dictate any end panel reinforcement required as well as the number of suspension lines required and the precise shape of the end panel will dictate the length of the suspension members.

[055] To properly manage the opening forces to which a parachute is subjected, it is frequently desirable to prolong the opening process of the parachute canopy by a technique known as reefing. It has been learned that the semi-cylindrical type parachute is compatible with all conventional reefing techniques such as peripheral reefing, spanwise reefing, or slider reefing. Because of its simplicity and low cost, it is expected that slider reefing will typically be chosen when reefing is desired for the semi-cylindrical type parachute.

[056] Because of the very simple shape, the semi-cylindrical type parachute **10** can easily be constructed in modular form. For large scale semi-cylindrical type parachutes, modularity will allow convenient disassembly for handling or repair.

[057] As with all parachutes of all types, the parachute size, the suspended weight, and the predicted aerodynamic forces will dictate the number, and strength, of all materials for the design and construction of a semi-cylindrical type parachute, in addition to dictating the strength of seams and joints that must be used.

[058] Since other modifications and changes varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

[059] Having thus described the invention, what is desired to be protected by Letters Patent is presented in the subsequently appended claims.